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## Original Article

# Analysis of phytate in raw and cooked potatoes

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## Abstract

The phytate (*myo*-inositol hexakisphosphate) contents of eight varieties of potato (*Solanum tuberosum*) stored at 4°C for approximately 3 months ranged from 0.111% to 0.269% of dry weight. The phytate was distributed evenly throughout raw unpeeled russet potatoes. There were no significant differences in phytate content between raw russet potatoes and those which had been boiled, baked or microwaved until fully cooked. French fries, potato chips and dehydrated potato flakes contained 0.174%, 0.095% and 0.205% phytate, respectively, on a dry weight basis. Only phytate was detected in raw russet potatoes, but smaller amounts of inositol pentakisphosphate were also present in the fries, chips and flakes. Sufficient phytate is consumed in cooked potatoes in the United States to comprise a substantial portion of the daily intake of this multifaceted phytochemical.

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**Keywords:** Phytate; Inositol hexakisphosphate; Potatoes; *Solanum tuberosum*

## 1. Introduction

Inositol hexakisphosphate (InsP<sub>6</sub>), commonly known as phytate, is a major component of plant storage organs such as seeds, roots and tubers, where it serves as a phosphate source for germination and growth (Reddy, 2002). Due to its ability to chelate and precipitate minerals, phytate can decrease the bioavailability of critical nutrients such as zinc, iron, calcium and magnesium in foods such as whole grains, nuts and legumes (Weaver and Kannan, 2002). At the same time, phytate may have beneficial roles as an antioxidant, anticarcinogen and more (Jenab and Thompson, 2002).

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On a dry weight basis, some roots and tubers contain nearly as much phytate as seeds. While raw seeds contain on average between 0.5% and 1.0% phytate (Phillippy, 2003), many starchy roots and tubers including yams, potatoes and cassava contain approximately 0.05–0.10% phytate on a wet weight basis (Phillippy et al., 2003). However, there is sparse data in the literature on phytate in roots and tubers, and the range in amounts depending on factors like genetic variety and soil fertility is not yet known.

The effects of processing on the phytate content of roots and tubers has not been studied using accurate methods of analysis. Prior to the development of HPLC methods for phytate and other inositol phosphates, the inositol bis- through pentakisphosphate products of phytate degradation were included in a single measurement of phytate phosphorus (Phillippy et al., 1988; Lehrfeld and Morris, 1992). The purpose of the research reported herein was to quantify the phytate contents of different varieties of raw and cooked potatoes and to obtain qualitative inositol phosphate profiles of some raw and processed potato products.

## **2. Materials and methods**

### *2.1. Materials*

Tubers from eight varieties of potatoes that had been stored at 4°C for approximately 3 months were obtained from Dr. Dennis Corsini, USDA-ARS Small Grains and Potato Germplasm Research Unit, Aberdeen, Idaho. Generic russet potatoes, LAY'S® Classic potato chips and Hungry Jack® mashed potato flakes were purchased at supermarkets in New Orleans. Cooked French fries were purchased at a McDonald's restaurant in Metairie, Louisiana. Dodecasodium phytate from rice was obtained from Sigma Chemical Company, St. Louis, Missouri. Coumarin was from Eastman Kodak Co., Rochester, New York. All other chemicals were reagent grade.

### *2.2. Cooking*

Unpeeled russet potatoes were boiled gently (simmered) 30 min in tap water, wrapped in aluminum foil and baked 60 min at 218°C in a VWR Scientific Products Model 1330 GM gravity convection oven (<http://www.vwrsp.com>) or microwaved 7.5 min for three potatoes at the Program Cook setting in a Welbilt Model MR99T microwave oven (Welbilt Appliance, Inc., New Hyde Park, New York).

### *2.3. Extraction*

Unpeeled raw potatoes were shredded with the thin (2 mm) shredding disk in a KitchenAid Model RRRFP600 (11 cup) food processor (<http://www.kitchenaid.com>). Cooked potatoes were chopped with a knife into 1 cm cubes. Twenty grams of shredded raw or chopped cooked potatoes was homogenized with 100 mL 0.75 N HCl for 60 s at low speed in a Waring commercial laboratory blender. Similarly, French fries were cut into 1 cm pieces, and 10 g was homogenized with 100 mL 0.75 N HCl. Potato chips and mashed potato flakes were ground with a mortar and pestle and stirred with 20 volumes (1:20, w/v) of 0.75 N HCl for 60 min. Sample 1.4 mL aliquots of

the above mixtures were centrifuged 5 min at 16,000*g* in an Eppendorf 5415 C microcentrifuge. One milliliter of the supernatant solution was injected with a plastic syringe through a tandem combination of a 225 mg Oasis HLB Plus extraction cartridge (Waters Corporation, Milford, MA) connected to a 25 mm Millex-HV 0.45  $\mu$ m pore-size filter unit (Millipore Corporation, Bedford, MA). The Oasis cartridges were used dry without any preconditioning. Variable amounts of solution passed through both the cartridge and filter and were collected, and subsequent calculations were made based on the concentrations of phytate in this eluate (Phillippy et al., 2003).

#### 2.4. HPLC

Fifty microliter aliquots of the sample solutions were separated by isocratic ion chromatography on a Dionex AG7/AS7 (guard/analytical) column combination with 0.25 N HNO<sub>3</sub> eluant at a flow rate of 1 mL/min. The eluate was combined with 0.1% Fe(NO<sub>3</sub>)<sub>3</sub> in 2% HClO<sub>4</sub> at a total flow rate of 1.5 mL/min in a plastic tee, and the UV absorbance was monitored at 290 nm in a Waters Lambda Max Model 480 LC Spectrophotometer (Phillippy and Johnston, 1985). Ten microgram external standards of dodecasodium phytate were analyzed before and after every two sample solutions. To obtain profiles of the total inositol phosphate composition, 10 mL of the extract was injected through a single 225 mg Oasis HLB Plus extraction cartridge connected to a 25 mm Millex-HV 0.45  $\mu$ m pore-size filter unit and rotary evaporated under vacuum at 40°C to dryness. The residue was dissolved in 1 mL distilled deionized H<sub>2</sub>O and filtered through an additional 25 mm Millex-HV filter unit. Fifty microliter aliquots of this 10-fold concentrated sample solution were separated by gradient ion chromatography similar to Phillippy and Bland (1988). Inositol phosphates were separated on the Dionex AG7/AS7 column combination with a gradient of 10–100% A (0.25 N HNO<sub>3</sub>) along with a countergradient of 90–0% B (20 mg/L coumarin) over 30 min followed by 5 min of 100% A at a flow rate of 1 mL/min. The eluate was combined with 0.1% Fe(NO<sub>3</sub>)<sub>3</sub> in 2% HClO<sub>4</sub> at a total flow rate of 1.5 mL/min in a plastic tee, and the absorbance was monitored at 290 nm.

#### 2.5. Moisture

Moisture was determined by the AOAC Official Method 984.25 in a convection oven (AOAC, 1995).

#### 2.6. Statistics

For phytate determinations triplicate potatoes or potato products were extracted, and duplicate sample solutions from each were analyzed. The duplicate results were averaged and used to calculate means and standard deviations with  $n = 3$ . For moisture determinations triplicate potato or duplicate potato products were sampled, assayed and averaged to calculate a mean. Data were subjected to one-way analysis of variance (ANOVA), and differences were considered significant at  $P < 0.05$ .

### 3. Results

Because the entire potato tuber is edible, we first measured the concentration of phytate in a raw russet potato divided into three sections approximately equivalent in mass. As seen in Fig. 1, there was little difference between the phytate content in the outer part containing the skin, the middle section and the inner portion. On a wet weight basis the phytate concentration ranged from  $0.046 \pm 0.017\%$  in the outer section to  $0.055 \pm 0.017\%$  in the inner section, and the differences were not significant.

To determine the genetic contribution to phytate content, eight varieties of potatoes were analyzed (Table 1). There were minor differences in phytate among the two varieties each of russet, red-skinned and white potatoes, which ranged from  $0.035 \pm 0.001\%$  for Kennebec to  $0.047 \pm 0.020\%$  for Russet Norkotah. The two yellow-fleshed varieties, Yellow Finn and German Butterball, had only about half as much phytate,  $0.023 \pm 0.015\%$  and  $0.021 \pm 0.002\%$ , respectively.

Three types of home cooking procedures were compared for their effects on phytate retention. The phytate contents in boiled and microwaved russet potatoes were 15% and 25%, respectively, lower than in raw and baked russets, but the changes were not significant at  $P < 0.05$  (Fig. 2). In addition, the phytate in the boiled potatoes did not change during subsequent refrigeration for up to 3 days at  $6^\circ\text{C}$  (Fig. 3).

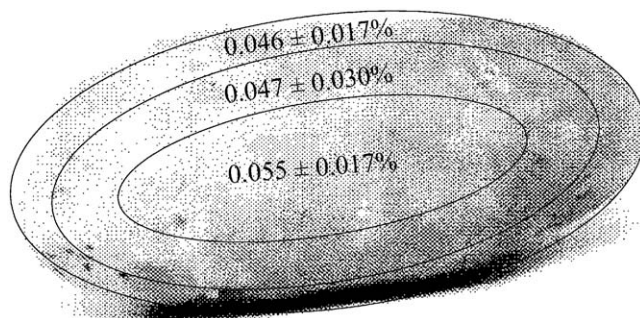


Fig. 1. Distribution of phytate in a raw russet potato tuber.

Table 1  
Phytate content of raw potatoes

Variety	Phytate (% of wet weight)	% Moisture	Phytate (% of dry weight)
Russet Burbank	$0.046 \pm 0.018$	82.9	$0.269 \pm 0.105$
Red LaSoda	$0.038 \pm 0.012$	81.4	$0.204 \pm 0.065$
Kennebec	$0.035 \pm 0.001$	80.5	$0.179 \pm 0.005$
Yellow Finn	$0.023 \pm 0.015$	81.5	$0.124 \pm 0.081$
Russet Norkotah	$0.047 \pm 0.020$	80.7	$0.244 \pm 0.104$
Norland	$0.042 \pm 0.018$	81.4	$0.226 \pm 0.097$
Superior	$0.044 \pm 0.014$	80.0	$0.220 \pm 0.070$
German Butterball	$0.021 \pm 0.002$	81.1	$0.111 \pm 0.011$

$n = 3$ .

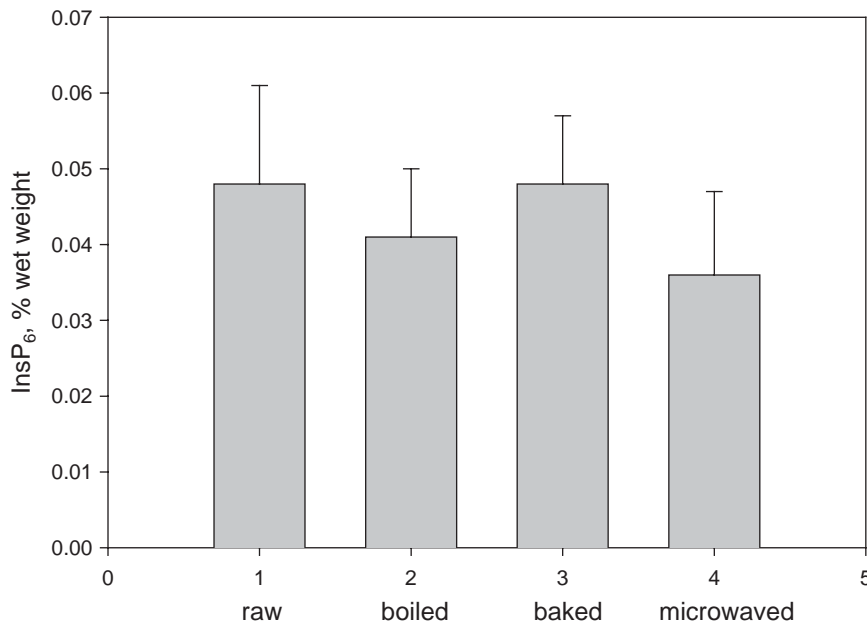


Fig. 2. Effect of cooking on phytate content of russet potatoes.

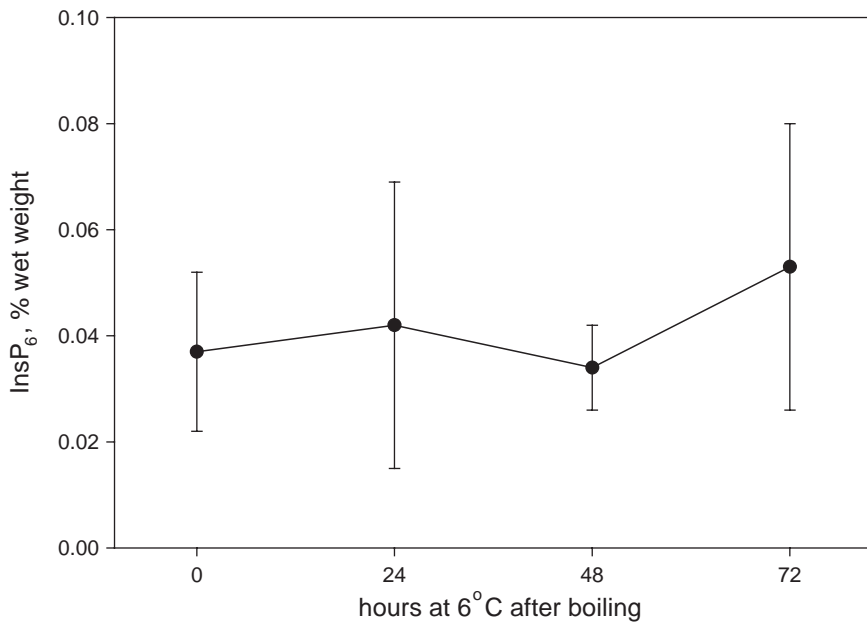


Fig. 3. Effect of storage at 6°C on phytate in boiled russet potatoes.

Finally, three commercially processed potato products were analyzed. Considerable amounts of phytate were found in Hungry Jack<sup>®</sup> mashed potato flakes, McDonald's French fries and LAY'S<sup>®</sup> Classic potato chips (Table 2). The total inositol phosphate composition was profiled for

Table 2

Phytate content of some processed potato products

Product	Phytate (% of wet weight)	% Moisture	Phytate (% of dry weight)
French fries	$0.106 \pm 0.038$	39.0	$0.174 \pm 0.062$
Dehydrated flakes	$0.205 \pm 0.003$	nd <sup>a</sup>	$0.205 \pm 0.003$
Potato chips	$0.094 \pm 0.031$	0.9	$0.095 \pm 0.031$

 $n = 3$ .<sup>a</sup>Not determined.

these three products and a raw russet potato (Fig. 4). The raw potato contained only InsP<sub>6</sub>, but the French fries also contained a small peak of D- and/or L-Ins(1,2,4,5,6)P<sub>5</sub>. InsP<sub>6</sub> was again the predominant inositol phosphate in mashed potato flakes and potato chips, but substantial amounts of D- and/or L-Ins(1,2,4,5,6)P<sub>5</sub> were also detected. In addition, some D- and/or L-Ins(1,2,3,4,5)P<sub>5</sub> was observed in the potato chips, but no detectable InsP<sub>4</sub> or InsP<sub>3</sub> isomers, which would have eluted between 10 and 19 min, were present in any potato product.

#### 4. Discussion

In this study the store-bought russet potatoes contained approximately 0.04% phytate according to wet weight. Previously, we measured 0.073% of the wet weight of russets to be phytate (Phillippy et al., 2003). Since these potatoes were purchased at different times, it is not known whether the difference was an effect of storage time or conditions or a result of their initial composition. In both studies the data were typical for the potatoes analyzed at that time, but in numerous additional analyses values exceeded 0.10% of wet weight, whereas a few times the amount was as low as 0.01%. Since there was less variation among the eight varieties of potatoes in Table 1, which were all stored under the same conditions, it is possible that storage may be an important factor. Likewise, growing conditions may contribute to the phytate content, because potatoes grown organically with cattle manure fertilizer contained only 0.024–0.086% phytate as dry weight (Thybo et al., 2002). Others have found amounts of phytate similar to those determined in our studies (Yoon et al., 1983; Ravindran et al., 1994; Khokhar et al., 1994).

Surprisingly, russet potatoes cooked in boiling water or convection or microwave ovens retained virtually all of their phytate. Although the potatoes were boiled unpeeled to reduce leaching, it is likely that cut potatoes would lose some phytate into the water. The commercially processed mashed potato flakes, French fries and potato chips all showed some evidence of thermal phytate degradation as evidenced by the presence of D- and/or L-Ins(1,2,4,5,6)P<sub>5</sub>, which is the predominant InsP<sub>5</sub> peak formed from phytate by nonenzymatic hydrolysis (Phillippy and Bland, 1988). However, on a dry weight basis the phytate contents of these products were not much different from the amounts in the raw potatoes that we analyzed, especially considering the potato chips contained 36% fat from the cooking oil. Thus it appears that relatively little phytate may be lost to the cooking oils during frying.

The average American consumes 26.8 kg of frozen potatoes such as French fries, 21.8 kg of fresh potatoes, 8.2 kg of dehydrated potato products and 7.3 kg of potato chips each year (Idaho

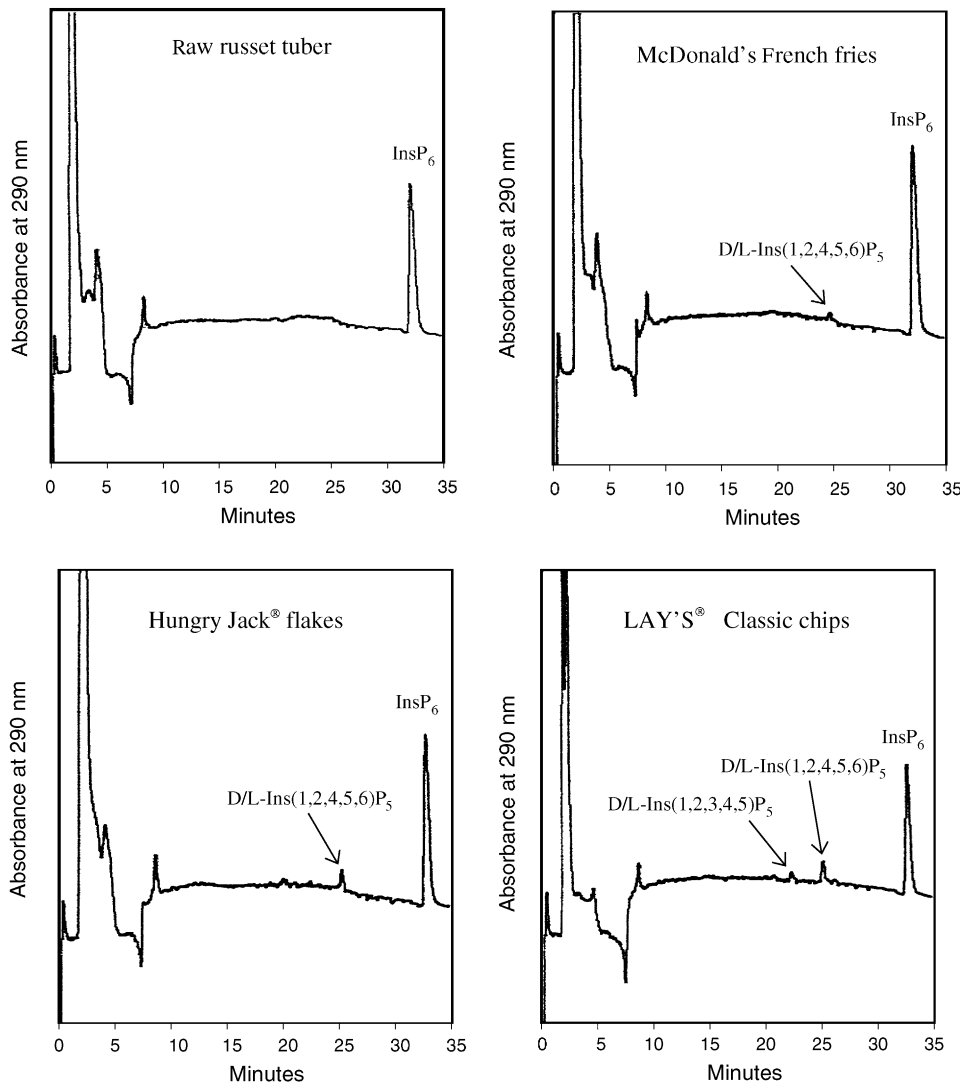


Fig. 4. Inositol phosphate chromatograms of raw and processed potatoes.

Potato Commission, 1998). Calculated from the data presented in this report, these foods provide an annual intake of 37 g, or just over 100 mg per day, per person of phytate from potatoes. Therefore, from a dietary perspective, potatoes constitute a significant portion of the estimated 631 and 746 mg per day of phytate consumed on average by omnivorous American females and males, respectively (Ellis et al., 1987).

For those anticipating the consequences of overnutrition, the phytate in potatoes may be beneficial, because it may help to prevent some of the harmful effects of the Western diet such as heart disease, diabetes, kidney stones and cancer (Jenab and Thompson, 2002). On the other



hand, it is not clear whether undernourished individuals may experience a reduced bioavailability of certain minerals. In cereals the sum of  $\text{InsP}_6$  and  $\text{InsP}_5$  needed to be reduced below  $0.5 \mu\text{mol/g}$  (0.033% phytate) on a dry weight basis in order to substantially increase the solubility of iron in the absence of iron absorption enhancers such as organic acids (Svanberg et al., 1993). The ascorbic acid content of potatoes helps to solubilize its iron (Fairweather-Tait, 1983), but the availability of iron to rats from extrusion-cooked potatoes was only 35.5% compared to 59.9% for extrusion-cooked maize (Fairweather-Tait et al., 1987). Lucarini et al. (2000) found the dialyzabilities of iron and zinc from potatoes were 13.6% and 34.7%, respectively. Whereas the zinc solubility after in vitro digestion of potatoes was greater than 90%, substitution of potatoes for white bread in meals containing chicken lowered the absorption of zinc in humans from 46.1% to 27.7% (Sandström et al., 1987). Similarly, in humans potatoes decreased the bioavailability of zinc from beef from 28.8% to 17.6% (Johnson et al., 1990). In human ileostomy subjects the absorption levels of iron, zinc, calcium and magnesium from isocaloric diets containing bean flakes were 0.3%, 12.4%, 15.4% and 7.0%, respectively, compared with 8.3%, 13.2%, 23.1% and 24.2%, respectively, for diets containing potato flakes (Langkilde et al., 1990). It should also be noted that oxalate, which is more detrimental to calcium bioavailability than phytate (Frossard et al., 2000), is present in much lower amounts, 0.03%, in potatoes (Bushway et al., 1984) compared with 1.26% in cassava (US Department of Agriculture, Agricultural Research Service, 1984), and the high amounts in various legumes (Massey et al., 2001).

## 5. Conclusions

On a dry weight basis potatoes contain less phytate than most seeds. Potato phytate is stable during common home cooking procedures such as boiling, baking and microwaving. Processed foods such as French fries, dehydrated potato flakes and potato chips retain much of their original phytate. Because potatoes may provide a substantial portion of the phytate in some diets, especially those deficient in whole grains, nuts and legumes, the nutritional consequences of phytate in potatoes should be investigated.

## 6. Disclaimer

Mention of names of companies or commercial products is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the United States Department of Agriculture over others not mentioned.

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